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Abstract: Dental implants have proven to be a successful treatment option in fully and partially edentulous patients, rendering long-term functional and esthetic outcomes. Various factors are crucial for predictable long-term peri-implant tissue stability, including the biologic width; the papilla height and the mucosal soft-tissue level; the amounts of soft-tissue volume and keratinized tissue; and the biotype of the mucosa. The biotype of the mucosa is congenitally set, whereas many other parameters can, to some extent, be influenced by the treatment itself. Clinically, the choice of the dental implant and the position in a vertical and horizontal direction can substantially influence the establishment of the biologic width and subsequently the location of the buccal mucosa and the papilla height. Current treatment concepts predominantly focus on providing optimized peri-implant soft-tissue conditions before the start of the prosthetic phase and insertion of the final reconstruction. These include refined surgical techniques and the use of materials from autogenous and xenogenic origins to augment soft-tissue volume and keratinized tissue around dental implants, thereby mimicking the appearance of natural teeth.

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Critical soft tissue dimensions along dental implants and treatment concepts

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Abstract

Dental implants have proven to be a successful treatment option in fully and partially edentulous patients rendering long-term functional and esthetic outcomes. Various factors are crucial for predictable long-term peri-implant tissue stability including the biologic width, the papilla height and the mucosal soft tissue level, the amount of soft tissue volume and keratinized tissue, and the biotype of the mucosa. The biotype of the mucosa is congenitally set, while many other parameters can, to some extent, be influenced by the treatment itself. Clinically, the choice of the dental implant and the position in a vertical and horizontal direction can substantially influence the establishment of the biologic width and, subsequently, the location of the buccal mucosa and the papilla height. Current treatment concepts predominantly focus on providing optimized peri-implant soft tissue conditions prior to the start of the prosthetic phase and the insertion of the final reconstruction. These include refined surgical techniques and materials from autogenous and xenogenic origin to augment soft tissue volume and keratinized tissue around dental implants, thereby mimicking the appearance of natural teeth.

Introduction

The introduction of dental implants has expanded the therapeutic options over the past decades in various clinical situations. Dental implants are being used to support removable and fixed reconstructions rendering long-term predictable outcomes on the implant level, but also on the reconstruction level in fully and partially edentulous patients, and patients with single tooth gaps (42, 63, 89). The high survival and success rates of dental implants are based on the basic understanding of the principle of osseointegration, the bone level and on the concept of the emergence profile or transition zone at the soft tissue level (2, 3, 12, 15, 99). In order to achieve predictable long-term tissue stability, functional, biologic and esthetic considerations need to be made. A variety of clinical and radiographic parameters were identified to predict and evaluate long-term success from a biologic (stability and tissue health) and from an esthetic aspect (subjective and objective parameters) (6, 10, 41) Factors to be considered include: i) the biologic width; ii) the papilla height and the soft tissue level (mucosal margin) on the buccal side of the implant; iii) the amount of soft tissue volume; iv) the amount of keratinized tissue; v) the biotype of the mucosa.

General considerations

Biologic width

Following the initial healing phase, a soft tissue attachment is established surrounding the dental implant. This can either occur with adaption of the mucoperiosteal flap around the transmucosal part of the implant (one-stage procedure) or subsequently to abutment connection (two-stage procedure). The structure of the peri-implant mucosa has been investigated in a number of preclinical studies (11-14, 31). In a canine study, the soft-tissue barrier at dental implants and teeth was compared (12). Histological analysis revealed that both soft tissue units had several features in common. A well-keratinized oral epithelium was located adjacent to both teeth and implants. Towards the tooth/the implant, this oral epithelium was continuous with a non-keratinized sulcular epithelium. The connection to the soft-tissue penetrating element was established by a thin

junctional epithelium facing the enamel or the transmucosal part of the implant, respectively. At the teeth, Sharpey's fibers originating from the underlying connective tissue extended into the root cementum in a complex three dimensional network. In contrast, the collagen fibers of the peri-implant mucosa run parallel to the surface of the transmucosal part of the implant (12). This more parallel direction of the fibers has later been confirmed in humans based on explanted, previously osseointegrated, implants (29, 88, 97). The blood supply of the periodontium at teeth is a key element during wound healing and the associated inflammatory processes. The vascular system at teeth is supplied through the vascular plexus of the periodontal ligament. The connective tissue part around implants contains only few vessels originating from the supra-periosteal blood vessels. Hence, it was speculated that the peri-implant mucosa could have an impaired defense system and that the fibroblast-rich layer of the peri-implant mucosa could overcome the poor blood flow by a proper seal against the oral environment (13). Presently available implant systems include a high number of different implant surfaces, which have shown to influence the remodeling processes of the peri-implant tissues. Whereas variable amounts of marginal bone loss have been associated with different implant systems (68), the surface texture of the implants did not appear to influence the healing pattern of the peri-implant mucosa during a 3-month healing period (19). Likewise, the establishment of the mucosal attachment seemed to be independent of the healing process, i.e. one-stage or two-stage procedures (2, 32).

Today, in general, two types of dental implants exist: i) one-piece and ii) two-piece implants. One-piece dental implants are comprised of an endosseous part, usually with a rather rough surface, and a transmucosal part, usually with a rather smooth surface. In contrast, two-piece dental implants only consist of the endosseous part. The endosseous and the transmucosal parts are separate and need to be joined during therapy. Two-piece dental implants are either available including a horizontal match (implant and abutment having the same diameter) or a horizontal mismatch (abutment diameter being smaller than the implant diameter). It has been demonstrated in preclinical studies that the magnitude and the extent of the inflammatory reaction surrounding dental

implants depends on the location of the implant-abutment interface relative to the bone crest (16, 17). Due to the nature of two-piece dental implants with a horizontal match, a typical saucer-type defect is observed. In order to limit the amount of the initial bone loss due to the naturally occurring remodeling processes and to keep the bone closer to the implant-abutment interface, newer implant designs include a horizontal mismatch. This results in a medialization of the biologic width and a minimized marginal bone resorption (27, 59, 114). Clinically, several studies demonstrated more favorable soft and hard tissue responses for implants with a horizontal mismatch (21, 49, 54, 69).

The placement of dental implants at or below the crestal bone level may cause vertical bone resorption (53, 119). This is in agreement with previous observations focusing on the location and the dimensions of the peri-implant attachment (11). Three months after implant placement, abutment connection was performed. Before the flaps were replaced and sutured on one side of the mandible, the vertical volume of the mucosa was reduced by 2 mm, while on the contralateral side the volume was maintained. After another 6 months, histologic analysis of the specimens showed that the epithelial structure of the peri-implant mucosa was located about 2 mm apical of the soft tissue margin and 1.3-1.8 mm from the bone crest in both groups. This experiment demonstrated that the peri-implant mucosa required a minimal dimension and, that bone resorption took place in case the biologic width was reduced (11).

Thus, the concept of the biological width appears to be independent of the implant system used with canine studies demonstrating that a similar mucosal attachment is formed adjacent to three different types of implant systems (Astra Tech Implant System; Branemark System; Straumann Dental Implant System) (3). Around all three implant systems, a junctional epithelium with a height of 1.5 – 2 mm and a connective tissue with a height of 1-2 mm were formed (3).

Further preclinical studies evaluated the material selected for the transmucosal part of the implant. In a canine study, the effect of the abutment material on the quality of the peri-implant mucosa was investigated (1). Abutments made of 4 different materials were tested. The mucosal attachment for titanium and aluminium-based sintered ceramic

abutments was similar. However, an impaired mucosal healing for abutments made of a gold alloy or dental porcelain was observed. Following abutment connection with such materials, the connective tissue of the peri-implant mucosa failed to develop at the abutment level. Consequently, some resorption of the marginal peri-implant bone took place and the mucosal attachment was formed against the surface of the endosseous part of the implant body (1).

Papilla height

The height of the papilla next to dental implants is one of the main parameters affecting the esthetic outcome. The presence or absence of the papilla is influenced by a variety of factors. Clinically, the presence of the papilla between two teeth depends on the vertical distance between the alveolar crest and the contact point of the adjacent teeth (111). In a clinical study, the papilla was present in 98% of the cases, if the vertical distance was less than or equal to 5 mm. When the vertical distance was 6 or 7 mm, the papilla was present in only 56% or 27% of the cases, respectively (111). Similar measurements were later performed between implants and teeth again evaluating the presence or absence of the papilla (26). It was demonstrated that the presence of the papilla depended on the vertical position of the periodontal attachment of the neighboring tooth. In cases with a vertical distance between the contact point and the bone crest of less than 5 mm, a complete papilla fill was obtained in all cases. When the distance was more than 5 mm, the presence of the papilla was reduced to a frequency of 50%.

In a clinical study, the mean papilla height between two adjacent implants was 3.4 mm, which is 1.5 mm less than between an implant and a natural tooth (109). This indicates that the anatomy of implants and teeth is substantially different and has a profound influence on the height of the papilla. Compared to natural teeth, the papillae at implant sites are reported to be significantly shorter (23).

These anatomical differences may in part explain that only weak scientific evidence (limited to case reports) exists for surgical approaches to predictably achieve papilla fill next to dental implants (46).

Beside the vertical position, the horizontal distance between the implant and the adjacent tooth needs to be considered. It was suggested that a minimal distance of 1.5 mm would be necessary to compensate for remodeling processes following the establishment of the biologic width (34, 35). The horizontal distance of bone between two adjacent implants and the respective presence of the papilla was evaluated in a clinical study (110). When the measured inter-implant distance was less than 3 mm, the amount of crestal bone loss was 1.04 mm. Only 0.45 mm of bone loss was noted with a distance of more than 3 mm. These findings indicated the need of a minimum of 3 mm distance between two adjacent implants for the presence of a normal papilla (110).

These distances may have to be reconsidered in the future following the introduction of dental implants with platform shifting (27, 59, 114). These implants have been shown to result in less peri-implant bone loss compared the standard types of implant (49). In addition, the saucer type defects have more frequently been reported with traditional implant and component configurations (52). The impact of these newer implant designs on treatment outcomes needs to be further evaluated in well-designed clinical studies.

Soft tissue volume

To date, there is no general consensus with respect to the amount of soft tissue volume (in a two- and three-dimensional way) needed for functional purposes on the buccal aspect of dental implants. However, based on scientific evidence in clinical studies, the amount of soft tissue volume can influence the esthetic outcome and may even in part compensate for missing bone on the buccal side of dental implants (9, 57). It has been demonstrated that the critical soft tissue dimension on the buccal aspect of dental implants appears to be 2 mm (61, 120). In cases with less than 2 mm of buccal soft tissue volume, the choice of the reconstruction material can significantly influence the esthetic outcome at implant sites with more favorable results for all-ceramic reconstructions compared to metal-ceramic reconstructions (59, 94, 127). In cases of more than 2 mm of soft tissue volume (buccal-oral dimension), the clinician is offered more options with respect to the reconstruction material without hampering the esthetic

outcome (57, 61). Unfortunately, the critical soft tissue dimension has not yet been evaluated in a three-dimensional way as a single parameter and, in a long-term clinical study (98). This is mainly due to the fact that currently available techniques to capture volume changes are optimized for hard tissues (cone beam computed tomography; CBCT) or are only occasionally used in dentistry (magnetic resonance imaging; MRI). More recently, preclinical and clinical studies evaluated new techniques and devices (such as intraoral scanners and the corresponding software tools) to evaluate soft tissue volume changes in a three-dimensional way (98, 106, 115). These techniques have been used to quantify soft tissue volume changes in single tooth gaps and to measure the height of the papilla (98, 106). Still, the critical soft tissue volume dimension on the buccal side of dental implants from a functional point of view is unknown.

Keratinized tissue

Controversy exists in the dental literature with respect to the question whether or not there is a need to augment the keratinized tissue around dental implants in cases with a lack of or a reduced width. A number of clinical studies suggested associations between an adequate width of keratinized tissue, higher survival rates of dental implants, health of the peri-implant mucosa, and an improved esthetic outcome (4, 7, 67). Based on three systematic reviews, this association could not be validated and it was concluded that there is insufficient or even a lack of evidence regarding the influence of the width of keratinized tissue on the survival rate and future mucosal recessions (20, 33, 126). In a clinical study, implants placed in edentulous patients were followed for a period of 5 years (100). It was demonstrated that implants with a reduced width of peri-implant keratinized tissue were more prone to lingual plaque accumulation and bleeding on probing as well as buccal soft tissue recession. This is supported by other clinical studies suggesting that an adequate width of keratinized tissue can reduce the risk for recessions (5, 8); a systematic review concluded that a certain amount of keratinized tissue may be advantageous to maintain peri-implant health (44). Even though controversy exists in

the dental literature, an increase in the width of keratinized tissue may be considered in order to simplify patient's oral hygiene and to maintain the mucosal tissue level.

Biotype

The mucosal biotype has been classified and reported in a variety of studies, identifying two types: a thin biotype with a high-scalloping mucosa and a thick biotype with a low-scalloping mucosa (85). Incidence and prevalence of both types varies quite significantly between different studies (22, 64, 83). This is most likely due to the fact that a number of methods were applied to define the tissue biotype ranging from periodontal probing, ultrasonic devices or even unknown methods (40, 70). An additional factor may be the different clinical threshold values used to assess the thickness of the mucosa (1 mm, 2 mm, 3 mm, visibility of periodontal probe) (22, 25, 93). Whereas the prevalence of the two biotypes was analyzed in cross-sectional studies, only few publications associated treatment outcomes of reconstruction on dental implants with the respective biotype (37, 66, 83). In a clinical study, immediate implants were placed in the esthetic zone and the amount of the recession on the buccal side of the crown was measured. It was demonstrated that a thin biotype was associated with an increased risk for recessions (37). These outcomes are supported by a number of other clinical studies demonstrating an increased rate of mucosal recessions with a thin biotype (24, 25, 64, 83). Hence, it is generally accepted that a thin tissue biotype is associated with an increased risk for unfavorable treatment outcomes following surgical interventions. In patients with a thin tissue biotype a more sophisticated treatment approach is therefore warranted. In situations with a thick tissue biotype a more straightforward approach may be chosen.

Selection of materials and techniques

Keratinized tissue

A variety of materials and techniques have been proposed over the years to increase the width of keratinized tissue around teeth and dental implants. Based on the outcomes of a systematic review, the use of an apically positioned flap (APF) is a predictable therapeutic option. It was also demonstrated that, by the addition of autogenous tissue, treatment outcomes could be improved. Therefore, an APF in combination with autogenous tissue has to be considered as the gold standard rendering the most predictable results (112). One of the major drawbacks related to studies identified in the systematic review was that none of these investigations was conducted around dental implants, but around teeth. The predictability of these techniques around implants has only recently been investigated in clinical studies (71, 75, 96). It remains speculation, whether the general principles when augmenting keratinized tissue may be transferred from teeth to dental implants.

In addition, disadvantages of the additional use of autogenous tissue are mainly attributed to the second surgical site (45, 96). The harvesting procedure most often performed at the palate requires an additional surgical site, thus increasing patient morbidity with pain and numbness the days following the surgery (30, 38, 45, 104). The quantity and quality of tissue that can be retrieved varies depending on the anatomical and individual shape of the palatal vault, the patient's gender and age. The location of the palatal vessels and nerves further limits the total amount that is available when obtaining autogenous soft tissue grafts (91, 104).

A variety of soft tissue substitutes have been described in the literature mainly derived from dermatology and originally developed to cover full thickness burn wounds and diabetic *ulcera* (74, 122). Main products used were of allogenic origin with a history in dental medicine now for more than 10 years (43). The results from various studies using allogenic devices to increase the width of keratinized tissue suggest that these soft tissue substitutes may have some clinical potential, but are associated with high shrinkage rates, a difficult clinical handling and histologic outcomes significantly different from

natural tissue (77, 79, 123, 124). In order to overcome these limitations, a collagen matrix with similar characteristics to the most commonly-used resorbable collagen membrane was developed. This collagen matrix (Prototype Mucograft®, Geistlich Pharma AG, Wolhusen, Switzerland) was designed and evaluated with an additional indication of enhancing the healing cascade and reducing scar retraction in periodontal defects, as a replacement for autogenous tissue to increase the width of keratinized tissue and for recession coverage (58, 71, 78, 82, 92, 116). Results from two randomized controlled clinical trials demonstrated that this newly developed collagen matrix was as effective and predictable as the gold standard, the connective tissue graft, for attaining a band of keratinized tissue around teeth and dental implants (96) and around implants only (75). In addition, patient reported outcomes were more favorable for the collagen matrix in both clinical studies. These data support the use of soft tissue substitutes in the future to reduce patient morbidity, while still rendering the desired clinical outcome (36).

Soft tissue volume

In a systematic review, the dental literature was searched for techniques and materials to augment soft tissue around dental implants and teeth in humans (112). With respect to soft tissue volume augmentation, only a limited number of studies has been identified rendering a weak level of evidence. The free gingival graft (FGG) and the subepithelial connective tissue graft (SCTG) were most often used to increase soft tissue volume in the oral cavity (112). In a clinical study, localized alveolar ridge defects were either treated using a FGG or a SCTG or left untreated and volumetric outcomes were three-dimensionally assessed (107). The greatest amount of soft tissue volume gain was observed for the SCTG group, with significant differences to control groups (FGG, untreated sites). Unfortunately, human studies are still scarce, mostly limited to case reports (103), modified surgical techniques to optimize existing soft tissue (86) and short-term results (39, 47, 98). The efficacy and long-term stability of augmented soft tissue volume around implants is unknown today.

Similar to the treatment with keratinized tissue, the harvesting procedure and the second surgical site can increase patient morbidity and alternative materials would be desirable. In order to overcome difficulties and limitations associated with the use of autogenous tissue, research has focused on the development and testing of alternative materials. From a technical, biological and clinical aspect, any potential device intended to be used as a replacement for autogenous connective tissue grafts needs to fulfill a number of criteria: i) successful integration of the device/graft into the surrounding tissue, ii) ability to degrade and being replaced by soft connective tissue and, and iii) three-dimensional volume stability over time since during regular function, compression and shear forces are constantly applied in the augmented area. In a series of in vitro and preclinical studies, a new three-dimensional volume stable collagen matrix (Prototype 3D collagen matrix, Geistlich Pharma AG, Wolhusen, Switzerland) was evaluated and tested to fulfill these criteria. This new collagen matrix was designed to serve as a replacement for autogenous grafts to increase the soft tissue quantity. In vitro experiments demonstrated that prototype collagen matrices were able to comply with simulated compression and shear forces mimicking those of a healing wound in the oral environment (76). Cultivation in a specifically designed bioreactor under constant perfusion with human fibroblasts resulted in a stiffening of the material. Hence, these prototype collagen matrices rendered mechanical volume stability and favorable biologic attributes (76). Two of the evaluated prototype collagen matrices were subsequently chosen and implanted in subcutaneous pouches in the back of mice. It was demonstrated that the network influenced connective tissue formation, angiogenesis and matrix degradation (117). One prototype collagen matrix characterized by a loose network was then tested in a canine model with a clinically more relevant chronic ridge defect. Volumetric and histologic measurements of augmented areas with either an autogenous SCTG or the collagen matrix demonstrated no significant differences rendering similar soft tissue volume augmentation and stability over an observation period of 3 months (113, 115). However, clinical results need to confirm these results before these soft tissue substitutes are available in daily practice. The autogenous soft tissue graft harvested from the

patient’s palate remains the gold standard to achieve soft tissue volume augmentation around teeth and at implant sites.

Treatment concepts

Time-point for soft tissue augmentation

Treatment concepts with dental implants can be classified according to the SAC (simple, advanced, complex) classification and include a variety of clinical and laboratory steps up to the insertion of the final reconstruction (28). Soft tissue augmentation/regeneration surgeries can be performed at several time-points depending on the initial classification, the location of the implant and the complexity of the case. Predominantly, two main time-points may be considered rendering the most predictable treatment outcomes: prior to implant placement and during the phase of tissue integration of the implant. Other time-points, such as following the insertion of the final reconstruction, are usually not considered as part of the regular treatment and are rather performed to compensate for tissue loss occurring over time. These rescue treatments are often associated with less predictability and require more refined technical and surgical skills (18).

The therapeutic approach to increase the width of keratinized tissue is indicated and most predictably performed prior to the insertion of the dental implant. The procedure of increasing the width of the keratinized tissue allows simplifying subsequent surgical interventions. Improving the quality of the soft tissues is frequently indicated, before major bone augmentation surgeries in order to minimize the risk of dehiscence, which often occur following such augmentations. Following the insertion of the dental implant, healing times vary depending on the implant type, design and surface, and the amount of bone that was simultaneously regenerated. Depending on the clinical situation at implant placement regarding bone and soft tissue conditions, healing times may vary. In the esthetic zone, 4-6 weeks prior to abutment connection appears as an optimal time-point to perform soft tissue volume augmentation. It is important to observe that soft tissue correction procedures do not interfere with bone and soft tissue healing necessary for proper tissue integration of the placed implants.

Optimizing soft and hard tissues prior to implant placement

The relationship between hard and soft tissues around implants is important for the esthetic outcome. In general, the outcome following reconstructive therapy regarding papilla volume and height at dental implants is less predictable than at natural teeth (109). Hence, the preservation of the papillary height during the entire therapy requires special attention. Following tooth extraction significant morphologic and histologic changes occur at the alveolar ridge. Recent research has focused on techniques to minimize this loss of hard and soft tissues between the day of extraction and the day of implant placement. Basically, two options exist: i) ridge preservation techniques following tooth extraction to minimize the effects of these biological processes, ii) orthodontic extrusion prior to tooth extraction to partly compensate for the effects of these biological processes. Controlling the hard and soft tissues prior to or after tooth extraction should, therefore, help achieving sufficient papilla fill.

Various ridge preservation techniques have been proposed. Some have been demonstrated to significantly maintain more ridge width and height compared to the healing by a blood clot alone (55, 72, 73, 108, 121, 125). More recent evidence suggest that more stable soft tissue dimensions can be obtained at 6-8 weeks post extraction by applying a slowly resorbable biomaterial within the extraction socket and covering it with an autogenous soft tissue punch from the palate (Fig. 1) (62). Furthermore, a smaller degree of resorption of the ridge profile was reported at 6 months compared to controls (60). When using orthodontic extrusion, the periodontal attachment including the alveolar bone can be advanced coronally. This has been reported to result in more esthetic soft and hard tissue dimensions and the maintenance of sufficient papilla volume (95).

In cases where a tooth was extracted some time before and a ridge deficiency is present, efforts are undertaken to regenerate missing bone and to enhance the soft tissue quality and quantity prior to or simultaneously with implant placement.

Regenerating bone volume in a horizontal and a vertical dimension can predictably be performed applying guided bone regeneration techniques (48, 50, 51). The amount of bone regeneration in a vertical dimension, however, and resulting papilla height are

limited by the height of the periodontal attachment at the adjacent natural teeth. Pre-existing attachment loss at neighboring teeth will, therefore, result in unfavorable papilla height. No surgical techniques are presently available allowing to overcome these biologic limitations.

Various options exist to increase the width of keratinized tissue around dental implants, thereby improving the soft tissue quality: i) APF/V; ii) APF/V plus autogenous tissue; iii) APF/V plus allogenic soft tissue substitute; iv) APF/V plus collagen matrix (36, 112). Based on the most recent scientific evidence, two techniques can currently be recommended for improving the soft tissue quality. Both techniques include the preparation of a soft tissue flap, which is then positioned more apically. Subsequently, a free gingival graft from the patient's palate (high level of clinical evidence) or a collagen matrix (lower level of clinical evidence) will be sutured over the exposed site (Fig. 2) (36, 75, 96).

Optimizing soft tissues after implant placement

A correct vertical and horizontal implant position facilitates the soft tissue management. Once osseointegration of the implant is achieved and basic remodeling processes are finished, various surgical techniques can be applied to further optimize and improve soft tissue volume and papilla height.

Current possibilities to increase soft tissue volume are limited to the use of autogenous tissue harvested from the patient's palate. One option includes elevating a full-thickness flap and subsequently placing a connective tissue graft beneath the buccal flap securing it with sutures (90). In order to leave the periosteum untouched and consequently minimize the amount of bone resorption due to the soft tissue surgical interventions, a modified incision design has been proposed elevating a split-thickness instead of a full-thickness flap (Figs 3A and B).

The soft tissue dimensions surrounding dental implants can further be improved using specific incision techniques at the time of abutment connection,: i) U-shaped incision, ii) T-shaped incision, iii) modified Palacci technique or iv) split-finger technique (46, 80, 81,

101, 118). All these techniques have in common that no soft tissue is removed. Instead, by use of the healing abutment the soft tissue is pushed towards the papillae or in a buccal direction (Figs 3C and D). In order to stabilize the mini-flaps creating papilla different suture techniques have been described mainly exhibiting a coronal traction (46, 80, 118).

Prior to the placement of the final restoration, the emergence profile can be contoured using the implant-supported provisional restorations (Figs 3E and F). Methods to create the emergence profile are either additive or subtractive thereby constantly changing the submucosal part of the provisional restoration until an optimal soft tissue contour is established around the implant (84, 87, 102, 105). When soft tissue deficiencies are still persisting, the lack of tissue may be compensated for by the prosthetic reconstruction. Prosthetic possibilities include over-contouring of the implant-borne crown moving the contact point of the final restorations more apically thus reducing the interdental space. Another option is to use pink porcelain to mimic soft tissues (65).

After the placement of the final implant-borne reconstruction, successful soft tissue augmentations are more difficult to perform. They should, therefore, be limited to a minimum and not be applied as a result of standard treatment planning. Interestingly, spontaneous improvement of the papilla height has been reported at dental implants over the long run without any clinical soft tissue manipulation (56).

Conclusions

The use of dental implants can render long-term functional and esthetic outcomes. Various factors are crucial for predictable long-term peri-implant tissue stability including the biologic width, the papilla height and the mucosal soft tissue level, the amount of soft tissue volume and keratinized tissue, and the biotype of the mucosa. While the biotype of the mucosa is congenitally set, other parameters can be influenced by the treatment itself. An ideal positioning of the dental implant in a vertical and horizontal direction results in an esthetically pleasing location of the buccal mucosa and sufficient papilla height. Recently refined surgical techniques and new materials for soft tissue

regeneration allow optimizing the amount of keratinized tissue and soft tissue volume prior to and to a lesser extent after the insertion of the final reconstruction. Thereby, the appearance of natural teeth can be mimicked using dental implant therapy.

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Figure legends

Figure 1.

Two clinical cases demonstrating morphologic changes following tooth extraction with (A-D) and without ridge preservation (E-G) up to 6 weeks.

A. Clinical situation prior to tooth extraction (11).

B. After extraction of tooth 11.

C. A biomaterial has been placed within the socket. The wound is closed using an autogenous soft tissue punch from the patient´s palate.

D. Situation at 6 weeks following tooth extraction.

E. Clinical situation prior to tooth extraction (22).

F. After extraction of tooth 22. No further treatment is applied leaving the site for spontaneous healing.

G. Situation at 6 weeks following tooth extraction. Note the significant changes of the tissue architecture with loss of bone and soft tissue compared to the clinical situation 6 weeks earlier.

Figure 2.

A. Clinical case with missing 35 and 36 and a narrow band of keratinized tissue prior to implant placement.

B. A mucoperiosteal flap has been elevated and sutured more apically.

C. A collagen matrix (Mucograft, Geistlich Pharma AG, Wolhusen, Switzerland) is sutured on top of the exposed periosteum.

D. Clinical situation 6 weeks later. The width of keratinized tissue is substantially increased compared to the initial situation.

Figure 3.

Clinical case demonstrating soft tissue management performed after implant placement in position 11.

A. Clinical situation 3 months post implant placement with concomitant bone augmentation. Note the missing tissue volume on the buccal side of region 11.

B. A mucoperiosteal flap was elevated. Subsequently, a connective tissue graft was harvested from the patient´s palate and placed in the prepared pouch underneath the buccal flap.

C. Six weeks later, a minimally invasive abutment connection with a roll flap was performed.

D. Healing one week following abutment connection.

E. Final emergence profile of peri-implant mucosa. The peri-implant soft tissue has been pushed to the buccal and interdental area using an implant-supported provisional restoration.

F. Final all-ceramic implant-borne reconstruction in situ 1 week following insertion.

Figure 1

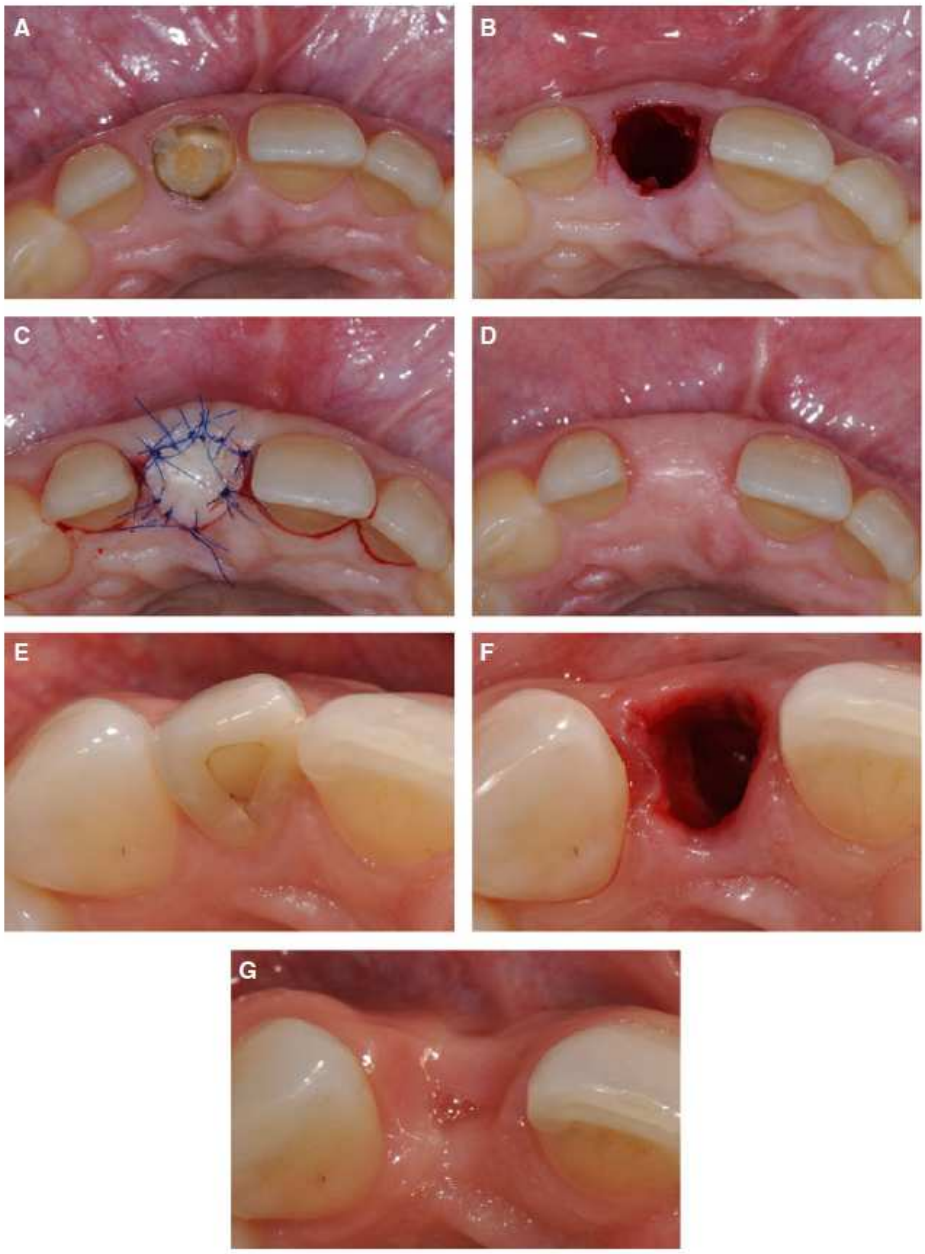

Figure 2

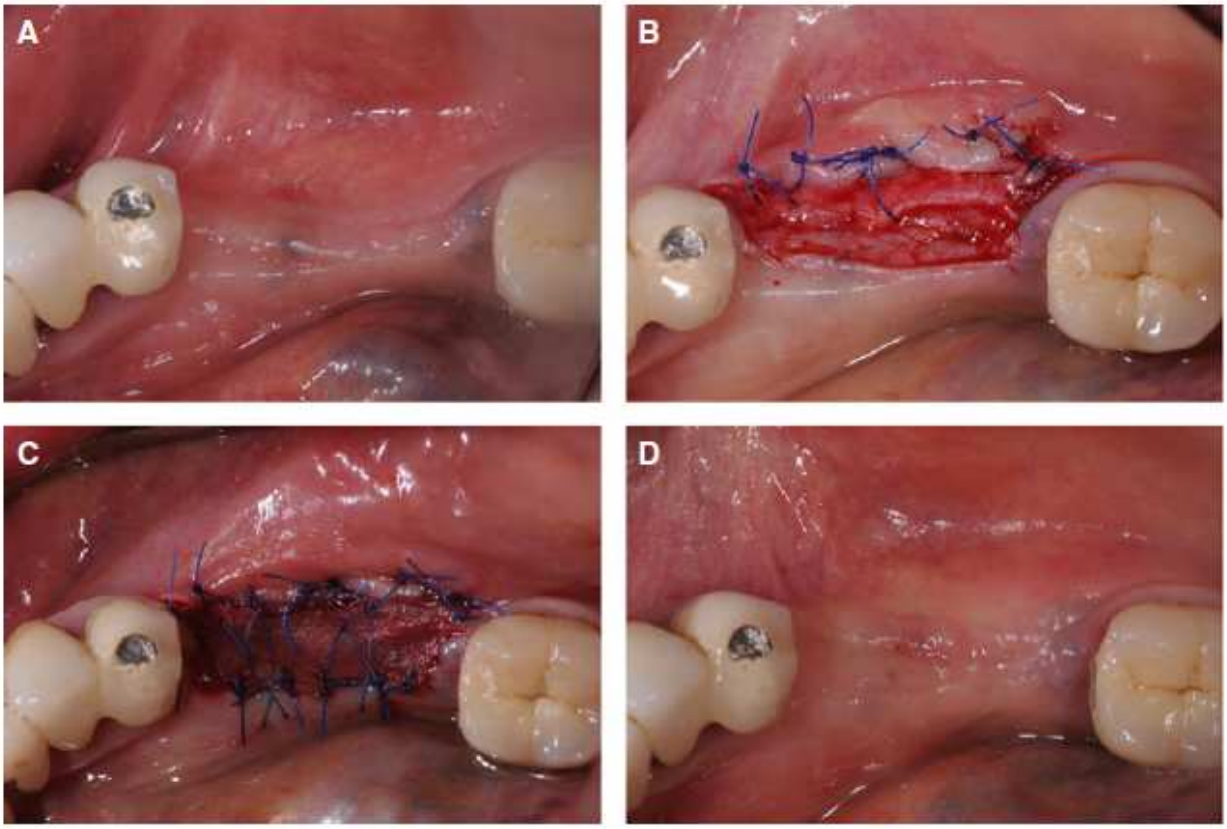

Figure 3